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# Timing is everything: radiocarbon dating multiple levels in the Mycenaean tholos tomb of Petroto, Achaia, Greece

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**ABSTRACT**

Reuse in Mycenaean *tholoi* (bee-hive shaped tombs) has been studied for centuries. Initially, bodies are interred on tomb floors, but moved after decomposition to make space for later burials. Extensive reuse can produce burial levels that are poorly understood often due to a lack of absolute dating. The Petroto tholos is a prime case study for dating multiple burial levels because all eight levels were sequential as later burials did not disturb previous depositions. The initial burial phase has been dated by ceramic chronology to the Late Helladic IIB-IIIA (ca. 1440–1400 BC). Radiocarbon dating of human bone samples yield for Level 7 (middle burial level) 3105 +/− 35 BP (1420–1305 cal BC) and for Level 3 (final burial) 2965 +/− 35 BP (1255–1120 cal BC). The ceramic and radiocarbon dates show that the tomb was used over for approximately 300 years during the Mycenaean period and never used again.

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## Introduction

### *Aegean chronology*

For the first half of the twentieth century, studies of the chronology of the Aegean Middle and Late Bronze Age (henceforth termed the Middle and Late Helladic) on the mainland of Greece (Table 1) had been dominated by ceramic chronologies from well-stratified contexts (e.g. Furumark 1941; French 1963; Mountjoy 1999).

These artifact typologies were then compared to similar examples from the Near East and Egypt. Their known dates of ruler successions allowed scholars to propose absolute chronologies for the Aegean (Warren and Hankey 1989). More recently, however, the traditional ceramic chronology has been supplemented and challenged by absolute dates obtained through scientific methodologies such as dendrochronology and radiocarbon dating.

The advent and subsequent refining of radiocarbon analysis techniques and more controlled sampling has led to fierce debates regarding the interpretation of the Aegean Bronze Age chronology (e.g. Wiener 2009). The Santorini/Thera eruption date is a prime example of this debate. The debate has produced two major camps: supporters of a "low" chronology (Warren and Hankey 1989; Wardle, Higham, and Kromer 2014; Wiener 2015) and supporters of a "high" chronology (Manning et al. 2006; Knapp and Manning 2016) whose radiocarbon data suggest that the Theran eruption took place approximately 100 years earlier, 1627–1610 BC (Friedrich et al. 2006; Bruins and van der Plicht 2014). These debates contextualize the state of the radiocarbon dating research in the Aegean Bronze Age as highly focused on one single event, the Theran eruption-the timing of which is an "anchor point" in any chronology.

Although there has been much interest in dating settlement sites in Mycenaean archaeology, there has been limited interest in radiocarbon dating Mycenaean tombs especially in cases of complex chronological sequences. In this article, we focus on dating burial levels in a Mycenaean tholos tomb in order to reconstruct its initial use and subsequent phases of reuse.

### *Previous studies of Mycenaean tomb reuse*

The reuse of tombs for later burials is a characteristic feature of Mycenaean mortuary practices that has been the subject of much research in past and recent years (Cavanagh and Mee 1978, 1998; Boyd 2002). In Mycenaean burials, there are three types of reuse. The first type of reuse is part of the normal mortuary practices sequence and attested early in the Mycenaean period in contexts such as the Shaft Graves at Mycenae. In these deeply built tombs, primary burials are often surrounded by small piles of bones at the edges of the tomb floor (Mylonas 1973). Increasingly complex mortuary practices may have prompted the construction of monumental tholoi and less labor-intensive chamber tombs. These tombs allowed for more

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**Table 1.** Chronology of middle and late Helladic periods for mainland Greece (modified[a] following Shelmerdine 1997, Table 1 and Voutsaki et al. 2013, Table 1).

| Time period | Abbreviation | Approximate dates (BC) |
|---|---|---|
| Middle Helladic III | MH III | 1800–1700 |
| Late Helladic I | LH I | 1700–1600 |
| Late Helladic IIA | LH IIA | 1580–1440 |
| Late Helladic IIB | LH IIB | 1440–1390 |
| Late Helladic IIIA | LH IIIA | 1390–1310 |
| Late Helladic IIIB | LH IIIB | 1310–1190 |
| Late Helladic IIIC | LH IIIC | 1190–1065 |

[a]The MH III and LH I dates were taken directly from the absolute dates in Voutsaki et al., while the LH II-IIIC dates were taken from Shelmerdine by combining the high and low (for LH II) or using the modified dates (for LH IIIA-C).

extensive reuse since they could be re-entered and new burials interred (Cavanagh and Mee 1998, 124–125). The burials in these tombs exhibit great variation indicative of multi-stage burial practices. Primary burials are often placed on the floor or within pits dug into the floor, and previous burials are piled up along the tomb edges or redeposited in pits.

The second type of reuse is also during the Mycenaean period but is not a continuous burial after burial. Traditional studies of ceramic chronology have identified examples of reuse via breaks in the artifact chronology (Cavanagh and Mee 1978). Cavanagh and Mee (1978, 1998, 96) suggest that initial use of tombs in LH I-II, followed by an LH IIIB hiatus of approximately 200 years, then some chamber tombs and tholoi possess a period of LH IIIC reuse. Lastly, in the later historic periods, Mycenaean tombs were again reused for burials (Aktypi 2014); these rituals are often termed as belonging to "hero cults" (Antonaccio 1995; Whitley 1995).

In some tombs, the reuse appears complex and excavations reveal multiple levels of burials. Examples of multiple burial levels have been noted in chamber tombs such as those at Kalkani near Mycenae (Wace 1932). The data from chamber tombs at Ayia Sotira demonstrate that tombs were reused and the construction of plastered floors occurred in the chambers and dromoi (sloping entryways) (Karkanas et al. 2012; Smith and Dabney 2014). Although relative chronology and mortuary research dominate Mycenaean archaeology, reconstructing multiple levels and timing of tomb reuse is seldom investigated.

Radiocarbon dates of Mycenaean contexts hardly exist; only two Mycenaean tholoi have been radiocarbon dated thus far. The tholos tomb of Voidokoilia (or Voikokilia) near Pylos in the south of the Peloponnese produced multiple radiocarbon dates based on charcoal samples that showed long and continuous use during the Mycenaean and later historic periods (Hurst and Lawn 1984, 214–215). Further north in central Greece, the tholos at Kazanaki in Thessaly was excavated in 2004 and archaeologists reconstructed two burial levels (Adrymi-Sismani and Alexandrou 2009). Radiocarbon samples dated by the Demokritos Laboratory at Athens resulted in dates of 1520–1400 and 1435–1330 BC for the reuse levels (Adrymi-Sismani and Alexandrou 2009). The short time intervals between burials suggest that the use of the tomb was likely continuous. This demonstrates that accurate radiocarbon dates are crucial for reconstructing reuse practices in Mycenaean tombs.

### *Issues and aims*

The ceramic chronological dating of tombs containing multi-stage mortuary practices has inherent flaws. Artifacts used to establish dating sequences are often only loosely associated with specific burials and do not take into account possible heirloom effects of older artifacts placed with more recent burials and not all artifacts are equally diagnostic. In addition, some human remains do not have associated artifacts. Therefore, given the state of this research, we focus on two basic questions:

(1) What are the absolute dates for the levels in the Petroto tholos?
(2) How do the dates help us reconstruct the tomb reuse actions in the Petroto tholos?

This article presents new radiocarbon dates for a Mycenaean tholos and uses the results to reconstruct the timing of reuse within the tomb. Reconstructing tomb reuse will aid in the interpretation of complex Mycenaean mortuary practices by understanding the intervals in which Mycenaean people reopened tombs to inter additional burials.

## Material

### *The region of Achaia*

The region of Achaia is located in the southern Greek mainland within the northwest corner of the Peloponnese (Figure 1).

Achaia is traditionally described as a "peripheral" region of the Mycenaean world, in comparison to the grand citadels and monumental tombs of the Argolid especially Mycenae (Figure 1), although this view has been re-evaluated recently in light of more systematic intra-regional studies (van den Berg 2011; Arena 2015). Achaia possesses rich regional variation observed in the, generally, smaller, less elaborate tombs with more rudimentary tomb architecture (Papadopoulos 1979). These aspects may be a result of regional preferences, possible contact with other regions, or even a lack of resources in the peripheral regions (Papadopoulos 1979). Additionally, Achaia does not contain evidence of the collapse in the LH IIIB (circa 1340–1190 BC) that is characteristic of the palatial sites in the Mycenaean "core" area. The mortuary record in Achaia is continuous in the Mycenaean period and persists into the Submycenaean period;

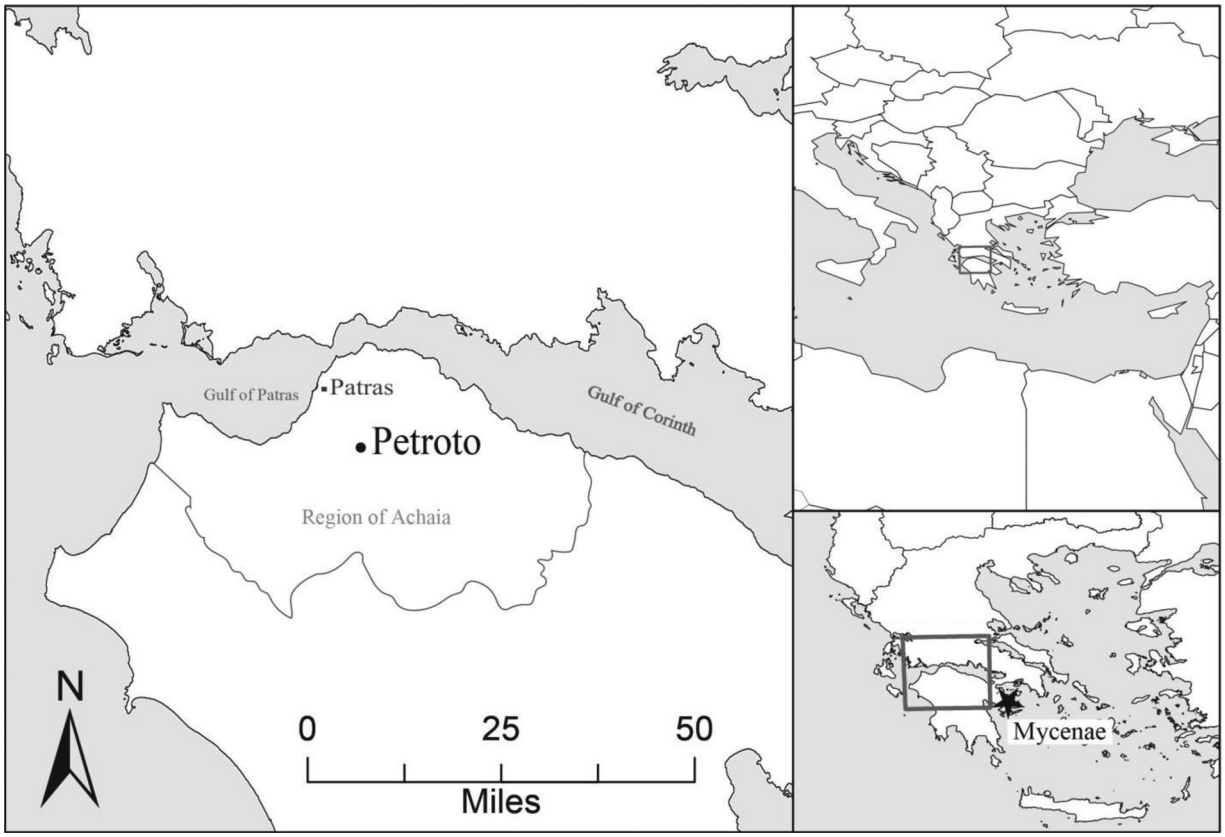


**Figure 1.** Map of region with study site (Petroto) and core site (Mycenae) indicated.

this may be a result of the region lacking destruction or the possibility of immigrants fleeing the destroyed centers (Papadopoulos 1979, 61).

### *Achaian tholoi*

There are a total of six tholoi in Achaia and all have evidence of reuse. The Kallithea tholos, located in the foothills outside of Patras, is part of a large Mycenaean cemetery containing the single tholos and 23 chamber tombs (Papadopoulos 1991). The tholos is said to be in use from the LH I-Protogeometric (approximately 1700–1000 BC) and possessed seven successive burial layers containing a minimum of 40 individuals and a horse burial on the floor (Papadopoulos 1991, 36; Graff 2011). The cemetery site at Portes is located in the south of Achaia, near the border with neighboring Elis. The cemetery contains two tholoi as well as tumuli and chamber tombs. Only one tholos at Portes has been systematically excavated to reveal a complex history of reuse. The tholos was used from LH II-IIIA but after a roof collapse it was partially cleared and cist graves were inserted into the chamber (Kolonas 2009, 40). Two more cist graves were also positioned directly outside of the tholos (Kolonas 2009, 40). While this reuse is different from Kallithea and Petroto, it is another example of tholoi reuse in Achaia. Lastly, two tholoi at Rhodia are currently under further study and likely possess some degree of tomb reuse as evidenced by highly fragmented human remains (Aktypi and Gazis 2016). Although the tombs have been dated to the Mycenaean period, the more detailed dating of the multiple levels is unknown.

### *The Petroto tholos tomb*

Petroto is situated on the western side of the oblong Mygdalia hill, upon which a Mycenaean settlement is currently under excavation (Morgan 2010). The tholos was discovered in 1989 during road construction and was partially damaged (Figure 2).

The rescue excavation was directed by Michalis Petropoulos of the Greek Archaeological Service in Patras. The tomb consisted of a round subterranean chamber constructed of crudely-cut limestone blocks arranged to form a bee-hive shaped tomb (Petropoulos 1995). It was constructed and first used during the early Mycenaean period (LH IIB-IIIA; 1440–1400 BC) and subsequently reused (Papazoglou-Manioudaki 2011). The excavators identified eight burial levels containing artifacts as well as human and animal remains (Figure 3).

However, only the floor level contained dateable artifacts making this complex history of mortuary reuse difficult to reconstruct without absolute dates for the subsequent burial levels within the tomb.

## Methods and calculation

For $^{14}C$ dating, we extracted the collagen fraction of the bones following a procedure originally developed

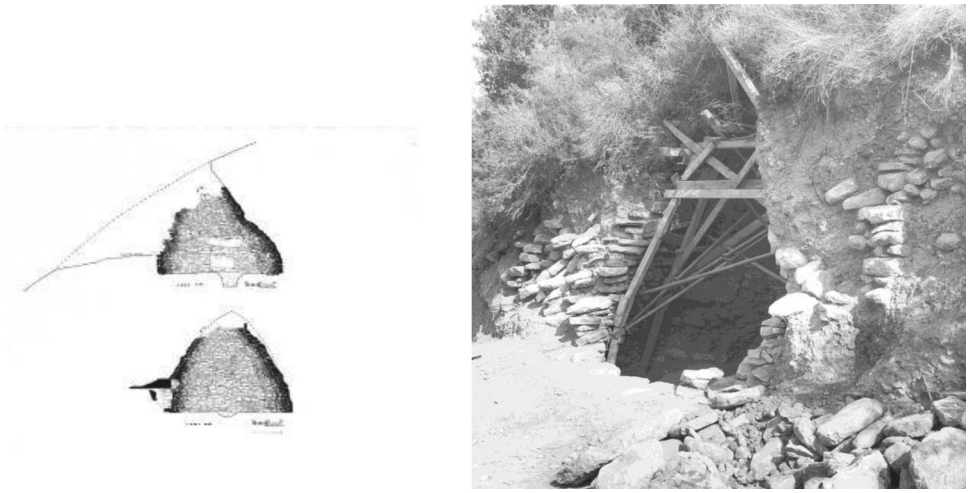

**Figure 2.** Plan and excavation photo of the tholos tomb.

by Longin (1971), supplemented by an additional final alkali bath for further purification. The main difficulty with collagen is chemical and/or bacterial degradation, which can result in compounds that easily combine with carbonaceous substances from the surrounding soil.

The most relevant quality parameters to judge the quality of the collagen (and thus of the $^{14}C$ date) are the yield, the carbon and nitrogen content of the collagen, and the stable isotope ratios $^{13}C/^{12}C$ and $^{15}N/^{14}N$. Fresh bone contains about 20% collagen by weight, with a carbon content of ca. 45% and a nitrogen content of ca. 15%. The atomic C/N ratio should be in the range 2.9–3.6 (DeNiro 1985).

The isotope ratios are expressed in delta (δ) values, which are defined as the deviation (expressed in per

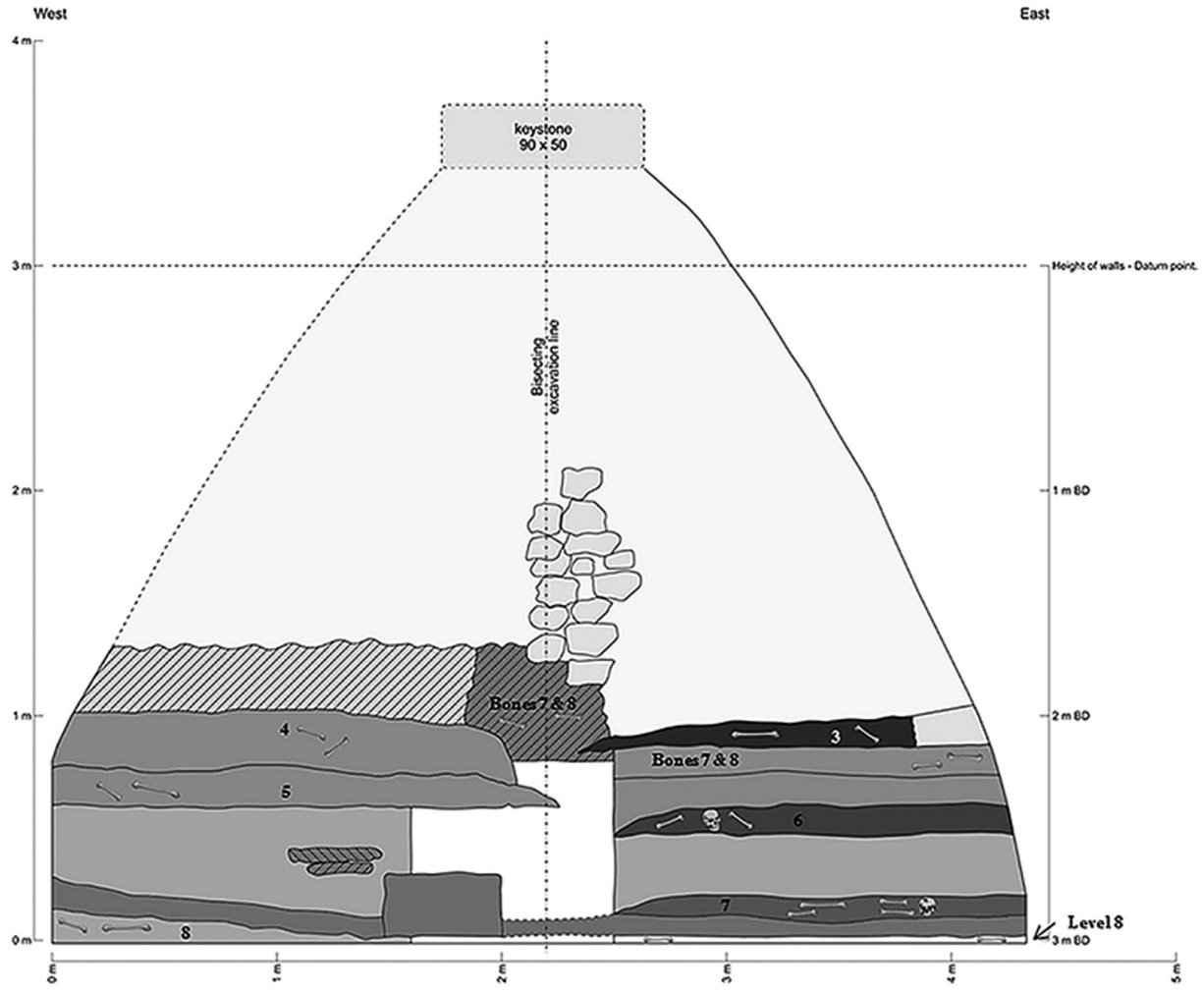


**Figure 3.** Section plan of the tomb with burial levels indicated with numbers. Light grey levels with no numbers are fill layers.

mil) of the rare to abundant isotope ratio from that of a reference material:

$$\delta^{13}C = \left( \frac{\left(\frac{^{13}C}{^{12}C}\right)\text{sample}}{\left(\frac{^{13}C}{^{12}C}\right)\text{standard}} - 1 \right) * 1000‰ \quad \text{and}$$

$$\delta^{15}\text{N} = \left( \frac{\left(\frac{^{15}N}{^{14}N}\right)\text{sample}}{\left(\frac{^{15}N}{^{14}N}\right)\text{standard}} - 1 \right) * 1000‰$$

For carbon, the reference material is belemnite carbonate (V-PDB); for nitrogen, the reference is ambient air (Mook and Streurman 1983).

The prepared and purified collagen is combusted into gas ($CO_2$ and $N_2$) using an Elemental Analyser, coupled to an Isotope Ratio Mass Spectrometer (IsoCube/IsoPrime). The IRMS provides the stable isotope ratios δ $^{13}$C and δ $^{15}$N as well as the C and N yields.

For $^{14}$C analysis, part of the $CO_2$ is routed to a cryogenic trap to collect the samples for further processing. The $CO_2$ is transferred into graphite powder by the reaction $CO_2 + 2H_2 \rightarrow 2H_2O + C$ at a temperature of 600°C and using Fe powder as catalyst (Aerts, van der Plicht, and Meijer 2001).

Next, the graphite is pressed into target holders for the ion source of the AMS. The AMS measures then the $^{14}C/^{12}C$ and $^{13}C/^{12}C$ ratios of the graphite (van der Plicht et al. 2000). From these numbers, the conventional $^{14}$C age is determined.

The latter is based on the Libby half-life value, oxalic acid as a reference and correction for isotopic fractionation using the δ $^{13}$C value of the sample (Mook and van der Plicht 1999). These ages are reported in BP by convention. For absolute dates, the conventional $^{14}$C ages need to be calibrated into calendar ages. This is done using the recommended calibration curve IntCal13 and the OxCal program (version 4.24, Reimer et al. 2013).

## Results

Nine samples of human bone were selected for dating. Samples of dense cortical long bone were primarily chosen due to their probability of containing more preserved collagen than more fragile cancellous bone. One sample was a rib fragment selected in order to preserve the integrity of the intact long bones. Unfortunately, only two samples (Levels 3 and 7) yielded good-quality collagen. This is not uncommon in arid areas. Nevertheless, the two good samples yield successful dates, enabling progress in obtaining new insights in chronology and usage of the tomb.

The dated results are shown in Table 2.

The table shows the laboratory code (GrA for Groningen AMS), the $^{14}$C age in BP, and the calibrated age ranges in BC. The latter is given at both the 1-sigma and 2-sigma confidence levels. All dates (BP and BC) are rounded to the nearest 5.

**Table 2.** Results of the bone analysis: C and N parameters, and isotopes ($^{13}$C, $^{14}$C and $^{15}$N).

| GrA | Age (BP) | δ $^{13}$C (‰) | C% | δ $^{15}$N (‰) | N% | C/N | Age (BC) (1-and 2σ) |
|---|---|---|---|---|---|---|---|
| 64716 | 2965 ± 35 | −18.66 | 41.7 | 8.84 | 15.1 | 3.2 | 1255–1120<br>1280–1055 |
| 64717 | 3105 ± 35 | −20.01 | 39.4 | 7.51 | 13.8 | 3.3 | 1420–1305<br>1440–1275 |

The table shows the C and N parameters and the stable isotope ratios δ $^{13}$C and δ $^{15}$N (in ‰). The C and N content and the C/N ratios are well within the expected range, and indicate excellent collagen preservation of the samples. Also, the stable isotope ratios $\delta^{13}$C and $\delta^{15}$N are well within expected range for human bone. They are consistent with a terrestrial diet.

For Level 3 (termed "Cist Burial") (Figure 4) sample GrA-64716 produced a date of 2965 ± 35 BP, calibrated to 1255–1120 BC (Figure 5). This burial was placed in a crudely constructed cist grave adjacent to wall A (Figure 3) within the tholos.

For Level 7 (termed "Theta Burial") (Figure 6) sample GrA-64717 produced a date of 3105 ± 35 BP, calibrated 1420-1305 BC (Figure 7).

## Discussion

The three known dates for the use of the tomb allow the reconstruction of the timing of the burial levels (Table 3).

As mentioned, the floor level (Level 8) has been dated by artifacts to transition period between LH IIB-IIIA (ca. 1440–1390 BC) and represents the initial burial phase in the tomb (Petropoulos 1990, 504; Papazoglou-Manioudaki 2011, 501). Between the floor and Level 8 was a layer of fill and wall debris. Level 7 is now dated by $^{14}$C to 1420–1305 BC suggesting no gap in burial activity. Levels 6, 5, and 4 are approximately dated by stratigraphy to 1305–1255 BC. Lastly, the final burial, Level 3, also had a successful radiocarbon sample and was dated to 1255–1120 BC (LH IIIB). This final deposit in the tomb represents the *terminus ante quem* for the tomb. This reconstruction of Petroto's history of use allows us is especially informative when placed within the regional chronology of Mycenaean Achaia and in relation to the change of mortuary practices through time.

First, the two radiocarbon dated samples from the Petroto tholos both fall after the traditional "low" and the radiocarbon calibrated "high" date for the Theran eruption. Thus, the Petroto dates do not greatly inform the debate between these chronologies and certainly do not warrant any shift within the Late Helladic chronology. Rather, the tomb and its dates are more informative when placed within the regional Achaia chronology. Mycenaean Achaia, with its lack of palatial

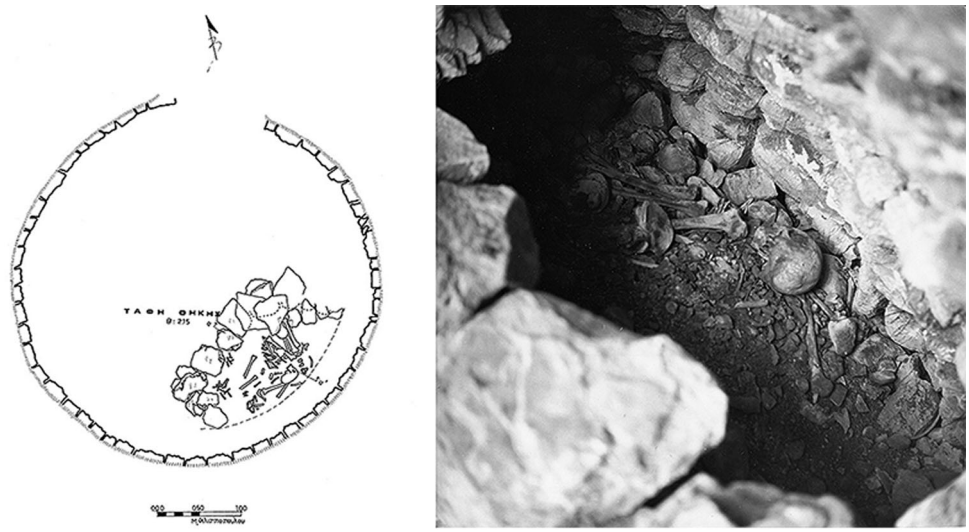

**Figure 4.** Plan and photo of Level 3 "Cist Burial".

structures and Linear B tablets, is widely considered to be a peripheral region (see Arena 2015 for recent debates) in which Mycenaean cultural practices trickled from palatial centers such as Mycenae (Figure 1). So is it unsurprising that the initial period of use in the Petroto tholos occurred in the LH IIB-IIIA period when many other Mycenaean tholoi were already abandoned presumably in favor of chamber tombs (Cavanagh and Mee 1998, 63–64). However, the presence of tholoi (interpreted as elite tombs) in peripheral regions such as Achaia has led some scholars to rethink the role of the Mycenaean periphery (Arena 2015).

Secondly, the reconstructed chronology of Petroto tomb shows evidence for continuous and extensive reuse. While reuse is common tholoi feature (Cavanagh and Mee 1998, 51–52), the multiple levels in Petroto are rare due to the numerous successive layers of burials. The other radiocarbon dated tholoi at Kazanki and Voidokoilia exhibit a slightly different burial chronology. The tholos at Voidokoilia has a long complex use that is difficult to unravel since the tholos was built into a Middle Helladic tumulus and the tholos was reused during subsequent historic periods. However, we do know that the tholos at Voidokoilia is one of the earliest tholos in Mainland Greece and may represent the introduction of this tomb type (Korres 1980; Voutsaki 1998, 53). At Kazanaki, the tholos was not so extensively reused and the burial

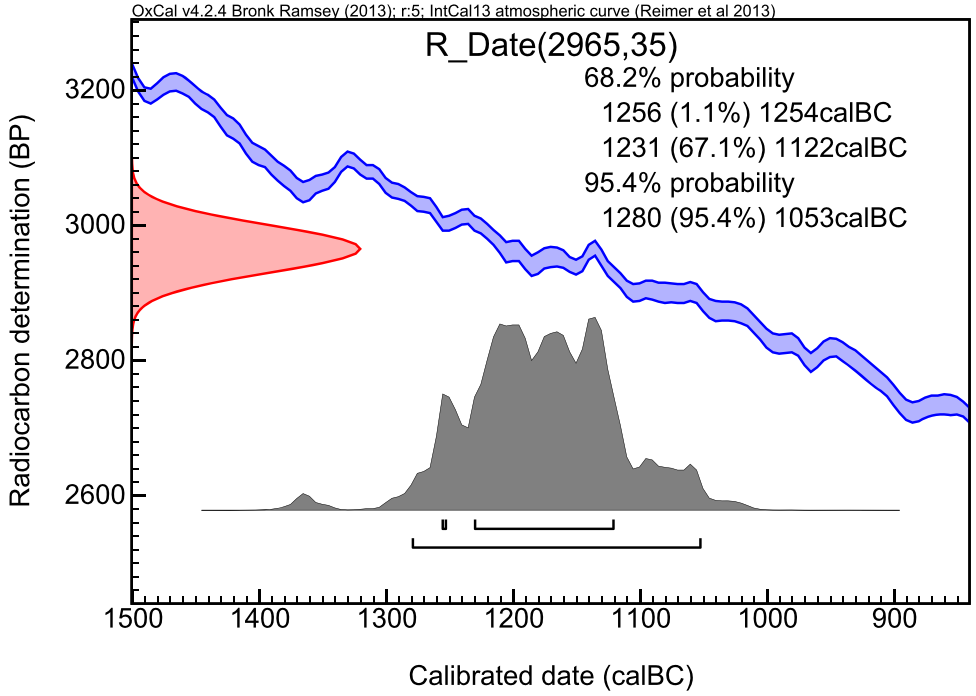


**Figure 5.** Graph showing the posterior density function of the calibrated date from Level 3.The dates have been rounded to the nearest 5.

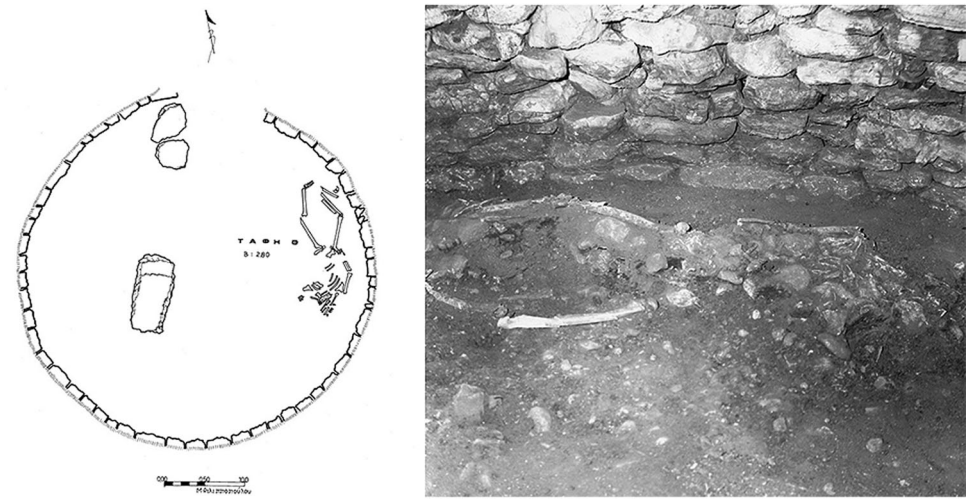

**Figure 6.** Plan and photo of Level 7 "Burial Theta."

record is less complex allowing us to make some comparisons between it and Petroto. First, the Kazanki tholos had only two burial levels and was used earlier than the tholos at Petroto. Also, the dating of the levels suggests continuous use similar to Petroto. However, the mortuary practices differ between the tombs with Kazanaki only having secondary burials while Petroto has evidence for primary internments in the later burial levels, such as Level 3. Additionally, the continuous use (i.e. reuse) of Petroto over many generations produced a tholos tomb with an estimated MNI of 62 individuals in the chamber and another two found in the stomion, while Kazanaki held only 9. In addition, nearly each level in the tomb exhibits different burial depositional practices. The diversity includes a single crouched burial (Level 3), multiple primary burials (Levels 4 and 5), a large bone pile representing 17 individuals (Level 6), a single extended burial on a bone pile (Level 7), and highly fragmented and commingled human remains on the tomb floor (Level 8) and under and adjacent to Level 3 (Bones 7 and 8) (Figure 3). Also, as can be seen in the tomb section (Figure 3), the reuse created levels that rose higher than the tomb door. At some point, the collapsed roof was utilized as the tomb entrance so that reuse of the tomb could continue.

For the Mycenaean community residing near the Petroto tholos, there were certainly other places available for burial. The Achaia Klauss chamber tomb cemetery was nearby and in use at the same time that the

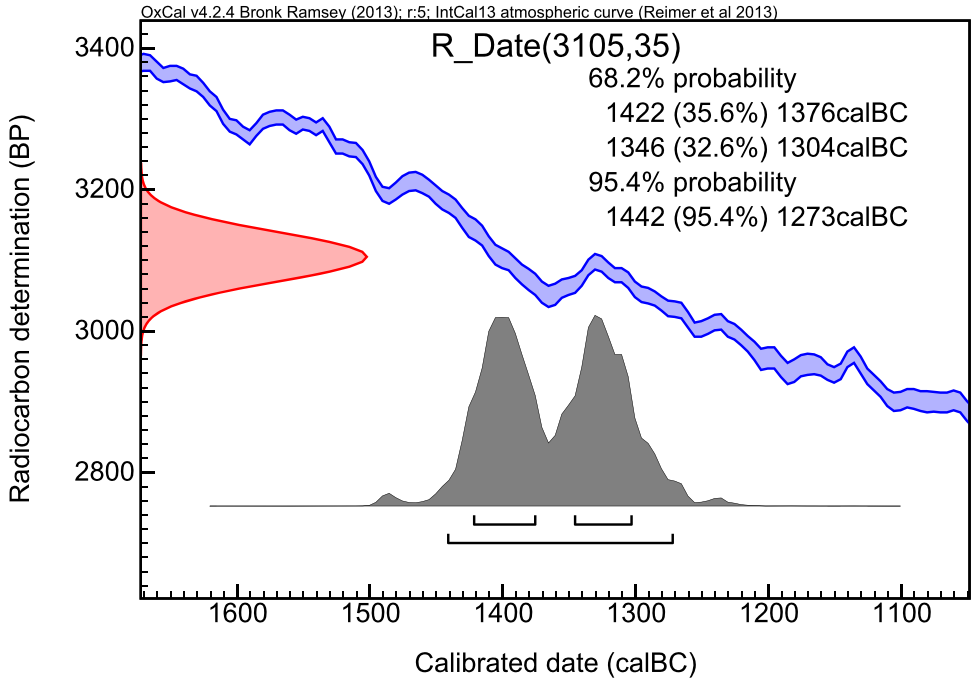


**Figure 7.** Graph showing the posterior density function of the calibrated date from Level 7.The dates have been rounded to the nearest 5.

**Table 3.** Reconstruction of the tomb levels[a].

| Burial level | Approximate dates | Time period |
|---|---|---|
| Level 3 | 1255–1120 cal. BC | LH IIIB-C |
| Level 4 | 1305–1255 BC | LH IIIB |
| Level 5 | | |
| Level 6 | | |
| Level 7 | 1420–1305 cal. BC | LH IIB-IIIA |
| Level 8 | 1440–1400 | LH IIB-IIIA |

[a]It should be noted that only Level 3 and 7 dates are calibrated radiocarbon dates. Level 8 was dated with associated artifacts using an accepted Mycenaean ceramic chronology, while Levels 4, 5, and 6 are dated stratigraphically since they are between two radiocarbon dated levels.

Petroto tholos was being reused (Papadopoulos 1991; Paschalidis and McGeorge 2009). Therefore, some people made a decision to bury the dead in the tholos rather than the nearby chamber tombs. Perhaps the decision was a practical one based on the time and energy it would have taken to reopen the chamber tomb when the tholos was partially collapsed and may have been approached from the top rather than the filled-in door and walkway. As Cavanagh and Mee state, "[t]he effort of cutting a new tomb was not worthwhile when an alternative ready for use was at hand, and when the social ties symbolized by the old family tomb were now broken" (Cavanagh and Mee 1978, 44). The decision and timing of the tomb reuse may be interpreted as pragmatic as Cavanagh and Mee suggest; however, the uncertain times after the palatial collapse in LH IIIB may have prompted local communities to make territorial claims via burial in ancestral tombs (Morris 1991). Both scenarios are possible for Petroto and future radiocarbon and tomb reuse studies will facilitate more nuanced interpretations by refining our knowledge of tomb chronology.

## Conclusion

The radiocarbon dating of the Petroto tholos has demonstrated that absolute dating in a reused Mycenaean tholos produces new results. Previously, the multiple levels in the Petroto tholos could not be fully interpreted because of the uncertain dating (Papazoglou-Manioudaki 2009, 512). The radiocarbon dates for Level 3 (2965 ± 35 BP; 1255–1120 cal BC) and for Level 7 (3105 ± 35 BP, 1420–1305 cal BC) demonstrate that despite the burial diversity, the human remains were all deposited in the Mycenaean period. This allowed us to reconstruct the history of the tomb and place the burials in a wider Mycenaean cultural context.

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